HABITAT AND BIOASSESSMENT OF THE MUSSELSHELL RIVER, MONTANA 1990 AND 1997

prepared for

The Montana Department of Environmental Quality
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prepared by

Wease Bollman
Rhithron Biological Associates
Missoula, Montana

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INTRODUCTION

Benthic assemblages are aptly applied to aquatic bioassessment since they are known to be important indicators of stream ecosystem health (Hynes 1970.) Long lives, complex life cycles and limited mobility mean that there is ample time for the benthic community to respond to cumulative effects of environmental perturbations. Multimetric approaches to bioassessment use attributes of the assemblage in an integrated way to measure overall biotic condition.

The additive multimetric approach designed by Plafkin et al. (1989) and adapted for use in the State of Montana has been defined as "... an array of measures or metrics that individually provide information on diverse biological attributes, and when integrated, provide an overall indication of biological condition." (Barbour et al. 1995). Community attributes that can contribute meaningfully to interpretation of benthic data include assemblage structure, sensitivity of community members to stress or pollution, and functional traits. Each metric component contributes an independent measure of the biotic integrity of a stream site; combining the components into a total score reduces variance and increases precision of the assessment. (Fore et al. 1995). Effectiveness of the integrated metrics depends on the applicability of the underlying model, which rests on a foundation of three essential elements (Bollman 1998). The first element is an appropriate stratification or classification of stream sites, typically, by ecoregion. Second, metrics must be selected based upon their ability to accurately express biological condition. Third, an adequate assessment of habitat conditions at each site to be studied must be done, to assist in the interpretation of metric outcomes.

This report summarizes bioassessment data collected in 1997 from the Musselshell River and uses a multimetric method, an adaptation of the U.S. EPA's Rapid Bioassessment Protocols (RBP III) (Plafkin et al. 1989). Macroinvertebrates were collected at six sites from the mouth of Daisy Dean Creek to Roundup, Montana. All sites lie within the Plains Ecoregions (specifically, within the Northwestern Great Plains Ecoregion) (Omernik et al. 1997).

Metric selection for this study was based on the recommendations found in the standard operating procedures for macroinvertebrate sampling and analysis of the Montana Department of Environmental Quality (MT DEQ) (Bukantis 1998). Implicit in the multimetric method and its associated habitat assessment is an assumption of correlative relationships between habitat parameters and the biotic metrics, in the absence of water quality impairment. These relationships may vary regionally, requiring an examination of habitat assessment elements and biotic metrics and a test of the presumed relationship between them. Assurance of the validity of association between habitat parameters and biotic metrics is particularly compelling in the Plains Ecoregions, since impairment of the biotic health of rivers in these two regions is generally the result of non-point pollution sources and/or habitat degradation. Agricultural activities, including cattle grazing and flow alteration, are predominant causes of stream degradation. The benthic assemblages of the Plains ecoregions and the performance of bioassessment metrics have not yet been examined thoroughly enough to determine whether or not the individual metrics or their integrated scores can discriminate impaired conditions from good biotic health. Bollman (1998) has recently studied the assemblages of the Montana Valleys and Foothill Prairies ecoregion, and has recommended a battery of metrics

specific to that ecoregion, which has been shown to be sensitive to impairment, related to habitat assessment parameters and consistent over replicated samples.

Habitat assessment enhances the interpretation of biological data (Barbour and Stribling 1991), because there is generally a direct response of the biological community to habitat degradation in the absence of water quality impairment. If biotic health appears more damaged than the habitat quality would predict, water pollution by metals, other toxicants, or high levels of organic and/or nutrient pollution might be suspected. On the other hand, an "artificial" elevation of biotic condition in the presence of habitat degradation may be due to the paradoxical effect of mild nutrient or organic enrichment in an oligotrophic setting. Habitat assessment data is even more important in the Plains ecoregions, where the relationships between habitat variables and benthic community characteristics remain largely unknown.

METHODS

Aquatic macroinvertebrates were sampled by personnel of the Montana Department of Environmental Quality (MT DEQ) from six sites on the Musselshell River in September 1997. For quality assurance purposes, a sampling at a single site was replicated; at the Deadman's Basin diversion, two samples were collected to provide an estimate of the variability inherent in the sampling and assessment methods. Habitat quality was visually evaluated at each site and reported by means of the habitat assessment protocols recommended by Bukantis (1998). Macroinvertebrate samples and associated habitat data were delivered to Rhithron Biological Associates, Missoula, Montana, for laboratory and data analyses.

In the laboratory, the RBP III sorting method was used to obtain subsamples of 300 (+/- 10%) organisms from each sample. Community structure, function, and sensitivity to impact were characterized for each subsample using two methods prescribed by MT DEQ (Bukantis 1998) for Plains ecoregions sites. First, data were evaluated using the Plains ecoregions reference. In this approach, benthic community attributes were compared to reference criteria established by MT DEQ for streams of both Plains ecoregions in the State. The ecoregional reference approach for the Plains ecoregions uses ten metrics (Bukantis 1998). In the second approach, a Musselshell River reference was established: the site near Daisy Dean Creek was chosen as the reference site to which the other sites were compared. This site received the highest habitat score of all sites in the study, and was judged unimpaired when compared to the ecoregion reference. Scoring criteria for the Musselshell River reference approach followed the system devised by Bollman (1997).

For both analyses, actual metric values were compared to the appropriate reference values to obtain metric scores. Biointegrity was estimated as the combined score for all metrics expressed as a percentage of the maximum possible score. As a result of the use of two alternative assessment approaches, two bioassessment scores are reported for each site.

Finally, these data are compared with data from an earlier study of the same Musselshell River sites, conducted in September of 1990. This comparison was limited by different taxonomic resolutions utilized in the two years, and by different subsample sizes employed.

RESULTS

Habitat assessment

Figure 1 compares habitat assessment results for the six sites in the two years of the study. Breakdown of total scores for 1997 assessments into the eight evaluated parameters is presented in Table 1.

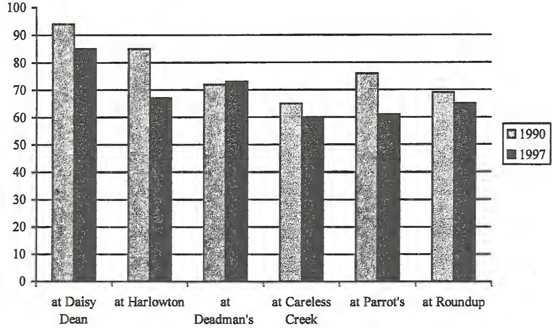

Figure 1. Total habitat scores, expressed as a percent of maximum habitat score, for six sites on the Musselshell River, evaluated in 1990 and in 1997. Sites are listed in upstream-to-downstream order. Habitat assessment methods were not identical in the two years, but many individual parameters were comparable between the two methods.

In both 1990 and 1997, the Musselshell River site at Daisy Dean Creek received the highest habitat scores. Habitat quality as assessed in 1997 generally appears to have decreased downstream from Daisy Dean Creek. Habitat was judged optimal at the uppermost site and sub-optimal at all other sites. Based on scores assigned in 1990, habitat at Daisy Dean Creek and at Harlowton was optimal in that year and sub-optimal at the other four sites. In no case does habitat assessment appear to indicate improvement in habitat quality between 1990 and 1997.

Limitations to habitat at the Daisy Dean Creek site were noted to be primarily due to reduced riffle area at the sampling site, which was assessed as marginal. Some loss of riparian vegetative width was also observed. At Harlowton, riffle development was judged even more compromised than at the upstream site. Substrate here was described as rather monotonous and of marginal quality with regards to habitat factors, though the field reports do not describe the substrate components. Streambanks were judged moderately unstable, but severe bank erosion upstream of the sampled site was described. Poor riparian zone width was noted on one side of the stream.

Sediment deposition was a major limiting factor to habitat quality at the Deadman's Basin diversion, with moderately unstable streambanks observed here as well. Flow status at this site was not evaluated on the field forms, and thus was not considered in the total habitat score for this site. The estimated discharge at this site (about 90 cfs), however, was the lowest discharge estimated for any of the six sites. At Careless Creek, flow status was assessed as marginal, though the estimated discharge was about 150 cfs. Riffle development was also considered marginal here, and moderate sediment deposition was noted with moderately unstable streambanks. In addition, poor riparian vegetative width further impaired assessed habitat quality.

Moderately unstable streambanks with marginal vegetative protection appeared to be the major impairment to habitat quality at Parrot's. Moderate sediment deposition was noted and a very unstable channel was observed at this site. Flow status received a sub-optimal rating, and discharge was estimated at about 150 cfs. At Roundup, the lowermost site, flow status was rated marginal though it was estimated at 200 cfs. Seasonal diminution of flow related to agricultural diversions was apparently suspected by the evaluator as a serious impairment of habitat quality at this site, similar to the situation at all sites from Deadman's Basin downward. Sediment deposition at this site was considered marginal, and streambanks were noted to be moderately unstable.

Bioassessment: the Plains Ecoregions reference

Macroinvertebrate taxa lists, metric results and other information for each sample are given in the Appendix. Figure 2 compares total bioassessment scores from integrated and summed metrics for Musselshell River sites, using the Plains Ecoregion

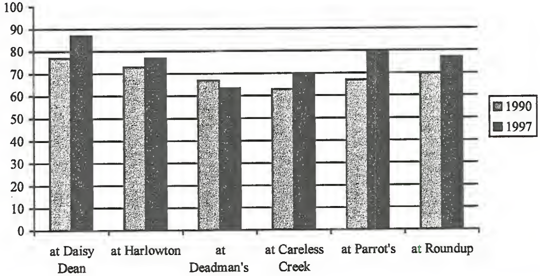

Figure 2. Total bioassessment scores for sites on the Musselshell River, based on the Plains Ecoregions reference. 1990 scores were recalculated based upon a reinterpretation of the taxon lists in the report on the data from that year (Bukantis 1991). Since taxonomic resolution and subsample sizes were not the same between years, scores are not entirely comparable; it is most likely that 1990 scores are somewhat underestimated.

reference as the standard for comparison. Data from both years are displayed. Table 2 summarizes this method and criteria. Breakdown of values and scores for each metric is presented in Tables 4a and 4b.

Total bioassessment scores improved between 1990 and 1997 at all sites except at the Deadman's Basin diversion, where the score decreased between the two years. At Daisy Dean Creek, the site was rated as fully supporting its use categories in both years' data. Partial use support characterized all remaining sites in 1990 and two remaining sites in 1997 (at Deadman's Basin diversion and at Careless Creek). 1997 data from the sites near Harlowton, at Parrot's, and at Roundup indicated full use support. Scores for replicated samples taken in 1997 at the Deadman's Basin site were gratifyingly similar ($V = 2\%$). Close similarity in scores between a single set of replicated samples suggests, but does not absolutely assure, that the sampling and assessment methods adequately represent the benthic community, and thus the biotic health of a site.

Bioassessment: the Musselshell River reference site

Figure 3 compares total bioassessment scores from integrated and summed metrics for Musselshell River sites, using the site near Daisy Dean Creek as the standard for comparison. Table 2 summarizes this method and criteria. Breakdown of values and scores for each metric is presented in Tables 4a and 4b.

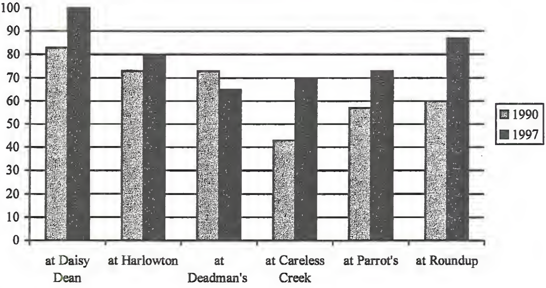

Figure 3. Total bioassessment scores for Musselshell River sites in two years of study, based on comparison with the reference site near Daisy Dean Creek in 1997. 1990 scores were recalculated based upon a reinterpretation of the taxon lists in the report on the data from that year (Bukantis 1991). Since taxonomic resolution and subsample sizes were not the same between years, scores are not entirely comparable; it is most likely that 1990 scores are somewhat underestimated.

Using the Musselshell River reference site as the basis for comparison accentuates the differences in bioassessment scores among sites within each year and between years.

Again, improvement in scores between the two years is apparent at every site except near the Deadman's Basin diversion, but the differences between years, in every case, appears greater.

Bioassessment scores calculated by this method indicate that the site at Daisy Dean Creek in 1990 was unimpaired, as were the sites near Harlowton and at Roundup in 1997. The site at Careless Creek partly supported its use designation; more serious impairment being indicated when a reference from the Musselshell River itself was used than when standards contrived for the ecoregion as a whole provided the comparison. Other sites were also rated partly supporting of uses in both years, though less impaired than the site at Careless Creek. More evident from this data is the diminution of biotic health in 1997 from Daisy Dean Creek downward to Deadman's Basin with the restoration of better biotic conditions upstream from Careless Creek, until near reference conditions are evident at the site near Roundup. There is a similar pattern in scores in 1990, but scores continued to diminish in that year from Daisy Dean all the way to Careless Creek, and the increase in scores did not attain as high a level by Roundup. Improvement in biotic health, measured in this way, was greatest between 1990 and 1997 at the Careless Creek and the Roundup sites; total bioassessment scores increased by nearly 30% at those locations between the two years.

Macroinvertebrate communities

Macroinvertebrate assemblages collected at Daisy Dean Creek in 1990 and 1997 were remarkably similar to one another. Very tolerant organisms dominated samples taken in both years; these included the mayfly *Tricorythodes minutus*, which comprised about 20% of both samples, the caddisflies *Hydropsyche* spp., and the blackfly *Simulium* sp. Overall community tolerance at this site was expressed by a biotic index score of 4.51 in 1990, and 4.43 in 1997, indicating assemblages moderately tolerant of nutrient pollution, relatively warm water temperatures and/or sediment deposition. Significantly, 21% of organisms collected in 1990 and 9% of those collected in 1997 were semi-voltine, or comparatively long-lived animals, requiring more than a single year to complete a life cycle. Their presence in these substantial numbers indicates adequate flow status with consequent habitat retention throughout the year.

In 1990 the benthic assemblage collected at Harlowton was comprised of a relatively high percentage of long-lived organisms (17%), mostly elmid beetles. In 1997, semi-voltine organisms were present, though diminished in abundance. The sample from that year contained 2% of these animals, including the perlid stonefly *Claassenia sabulosa.* Dominant organisms in 1990 included the tolerant mayfly *Tricorythodes minutus*, which continued to dominate the assemblage in 1997. Interestingly, the caddisfly *Helicopsyche borealis* and the amphipod *Hyallela azteca,* both notoriously tolerant of warm water temperatures, were among the dominant organisms collected in 1990, but were not collected in 1997, suggesting that water temperatures may have been cooler in the later year. While midges comprised only 4% of the 1990 sample, 30% of organisms collected in 1997 were midges, including those in the Cricotopus Trifascia Group (20% of all animals in the assemblage), which are highly tolerant of sediment deposition. Overall community tolerance seemed to increase between the two years as evidenced by the biotic index value, which changed from 4.20 in 1990 to 5.04 in 1997.

The increase in tolerance, however, may be an artifact of the difference in subsample sizes between the years.

At the site just below the Deadman's Basin diversion, biotic index scores also suggested that community tolerance increased here between the two years of study as well. Interestingly, the dominant organism collected in 1990, a turbellarian flatworm, comprising 15% of the sample, was not present in either of the two samples collected in 1997. Abundance of these creatures suggests ample groundwater inflow. Samples collected in 1997 were instead dominated by the tolerant caddisflies *Hydropsyche* spp. and the sediment tolerant midges in the Cricotopus Trifascia Group.

Although the total bioassessment scores calculated for the site near Careless Creek suggest that improvement in biotic health occurred between the two years, some elements of the data from 1997 strongly imply that impairment here was worse than the condition reflected in the bioassessment score. Only 100 benthic organisms were collected in the entire sample, indicating a severely depauperate community. In addition, no long-lived organisms were present in the sample, although they comprised 4% of the collected assemblage in 1990. These observations suggest that dewatering and consequent habitat loss may have severely impaired biotic health of the Musselshell River at Careless Creek in 1997. Such a degree of loss of macroinvertebrate fauna and long-lived taxa may also be due to severe instability of benthic substrates; the cause of the impairment cannot be absolutely distinguished.

Much the same situation is apparent from the data collected at the site at Parrot's. A total of 181 organisms were collected at this site in 1997, and long-lived organisms were not present in the sample. Dewatering, or another severe impact, is again suggested by these data. The sample collected at Parrot's in 1997 was quite similar to that collected at Careless Creek in the same year. Both assemblages were dominated by the tolerant perlodid stonefly *Isogenoides* sp., the mayfly *Rhithrogena* sp. and the filter-feeding blackfly *Simulium* sp. The abundance of the stonefly and the heptageniid mayfly suggest that water quality is relatively unimpaired by nutrients or other pollutants at these sites; biotic indices were 2.53 at Careless Creek and 3.11 at Parrot's. Again, the low biotic indices may be an artifact of small sample sizes. In 1990, samples from the two sites were similar as well, though quite different from those collected in 1997. Four percent of organisms collected in that year from the two sites were long-lived. Assemblages were dominated by nutrient and sediment tolerant forms, including the mayfly *Tricorythodes minutus* and the caddisfly *Cheumatopsyche* sp. Biotic indices in were 4.24 at Careless Creek and 3.76 at Parrot's, though once again, these are probably lower than they would have been if larger subsample sizes had been utilized.

In 1997, the biotic health of the Musselshell River site near Roundup approximated reference conditions at the Daisy Dean Creek site. While long-lived taxa were not abundant here in 1997, they were represented by two taxa, the elmid beetle *Ordobrevia nubifera* and the dragonfly *Ophiogomphus* sp. In addition, depauperate conditions were not evident here, as they were at the two nearest upstream sites. Nine different mayfly taxa were collected in 1997 at Roundup, suggesting that water quality was good. The moderate sediment deposition estimated in the habitat assessment was reflected in the abundance of sediment tolerant taxa, including the baetid *Acentrella turbida* and the caddisfly *Cheumatopsyche* sp.

CONCLUSIONS

- Judging by entries on the field data forms, it appeared that flow status was difficult to evaluate in 1997 for two Musselshell River sites below Harlowton. Seasonal diminution of flow related to agricultural diversions was apparently suspected by the evaluator as a serious impairment of habitat quality. This suspicion is supported by the macroinvertebrate data. Dewatering could have been a major source of impairment to biotic health at the Careless Creek site as well as the site at Parrot's, evidenced by low total abundance of organisms and lack of long-lived taxa. Other causes of taxa loss include severe instability of benthic substrates, which could also have contributed to the observed effect. The degree of impairment is not strongly evident in bioassessment scores for these sites thus these scores must be interpreted cautiously. The data suggests that impairment is worse at these sites than indicated by the bioassessment scores.
- Long-lived taxa were present at Daisy Dean Creek, Harlowton, Deadman's Basin and Roundup in 1997, suggesting that river flows adequate to maintain these organisms were present at these sites year-round.
- Biotic health of the Musselshell River at Daisy Dean Creek and at Roundup appeared to be unimpaired, though evidence of sediment deposition was apparent at both sites.
- Sediment tolerant taxa were also dominant at the Deadman's Basin diversion site.
- For quality assurance purposes, a single set of replicate samples was collected at the Deadman's Basin diversion site. These samples were used to provide an estimate of the variability in total bioassessment scores for the Musselshell River, given the sampling and assessment methods used. Comparing total bioassessment scores gave a coefficient of variability (*V*) of 2%, indicating very good replication for this site and suggesting, though not assuring, low variability and good quality assurance for the overall study. A comparison of individual metrics and taxa from the two samples can be found in the Appendix.

TABLES

Table 1. Stream and riparian habitat assessment: Musselshell River. September 1997.

Max. possible score	Location:	at Daisy Dean	at Harlowton	at Deadman's basin	at Careless Creek	at Parrot's	at Roundup
	Parameter						
10	riffle development	5	3	9	4	8	6
10	substrate development	10	5	9	9	6	8
20	embeddedness	16	15	15	15	16	18
20	channel alteration	20	15	16	16	15	16
20	sediment deposition	15	13	9	6	7	8
20	flow status	20	20	n.a.	10	15	6
10/10	bank stability (right/left)	9 / 9	5 / 5	4 / 4	5 / 5	3 / 3	5 / 5
10/10	bank vegetative cover (right/left)	10 / 10	8 / 10	9 / 5	7 / 7	4 / 4	8 / 8
10/10	riparian width (right/left)	6 / 6	2 / 6	6 / 10	2 / 9	8 / 8	8 / 8
160	TOTAL:	136	107	(96)[2]	95	97	104
PERCENT OF MAXIMUM:		85	67	69	60	61	65
CONDITION[1]:		OPTIMAL	SUB-OPTIMAL	SUB-OPTIMAL	SUB-OPTIMAL	SUB-OPTIMAL	SUB-OPTIMAL

1. Condition categories: Optimal > 81% of maximum score; Sub-optimal 75 - 56%; Marginal 49 - 29%; Poor <23%. From Plafkin et al. 1988.
2. Field sheet does not show a value recorded for the "flow status" parameter; total habitat score was calculated without considering this factor.

Table 2. Metrics and scoring criteria for Plains Ecoregions streams (Bukantis 1998).

	Scoring Criteria			
metric	3	2	1	0
Taxa richness	>24	24 - 18	18 - 12	<12
EPT richness	>8	8 - 6	5 - 3	<3
Biotic index	<5	5 - 6	6 - 7	>7
% dominant taxon	<30	30 - 45	45 - 60	>60
% collector (gatherers + filterers)	<60	60 - 80	80 - 95	>95
% EPT	>50	50 - 30	30 - 10	<10
Shannon diversity	>3.0	3.0 – 2.4	2.4 – 1.8	<1.8
% scrapers + shredders	>30	30 - 15	15 - 3	<3
Predator taxa richness	>5	4 - 5	3 - 4	<3
% multivoltine	<40	40 - 60	60 - 80	>80

Table 3. Criteria for the assignment of support classifications / standards violation thresholds (from Bukantis, 1997)

% Comparability to reference	Use support
>75	Full support--standards not violated
25-75	Partial support--moderate impairment--standards violated
<25	Non-support--severe impairment--standards violated

Table 4a. Metric values, percent of ecoregional reference, and bioassessments for six Musselshell River sites. September 5, 1990.

Metric	*at Daisy Dean*	*at Harlowton*	*at Deadman's Basin*	*at Careless Ck.*	*at Parrot's*	*at Roundup*
Taxa richness	21	18	14	12	13	18
EPT richness	12	8	5	9	8	11
Biotic index	4.51	4.20	4.49	4.24	3.26	3.45
% Dominant taxon	18	32	15	39	24	35
% Collectors	79	76	66	94	89	91
% EPT	63	72	57	95	93	87
Shannon H	3.97	3.30	3.35	2.58	3.04	3.03
% Scrapers plus shredders	11	16	2	3	9	4
# Predator taxa	1	2	3	1	1	1
% Multivoltine	20	22	37	20	23	14
Metric score						
Taxa richness	2	2	1	1	1	2
EPT richness	3	2	1	3	2	3
Biotic index	3	3	3	3	3	3
% Dominant taxon	3	2	3	2	3	2
% Collectors	2	2	2	1	1	1
% EPT	3	3	3	3	3	3
Shannon H	3	3	3	2	3	3
% Scrapers plus shredders	1	2	0	1	1	1
# Predator taxa	0	0	1	0	0	0
% Multivoltine	3	3	3	3	3	3
Total score (maximum = 30)	23	22	20	19	20	21
Percent of maximum	77	73	67	63	67	70
Use support*	**FULL**	**PART**	**PART**	**PART**	**PART**	**PART**

* See table 3 for use support designations

Table 4b. Metric values, percent of ecoregional reference, and bioassessments for six Musselshell River sites. September, 1997.

Metric	at *Daisy Dean*	at *Harlowton*	at *Deadman's Basin (Rep.1)*	at *Deadman's Basin (Rep.2)*	at *Careless Ck.*	at *Parrot's*	at *Roundup*
Taxa richness	24	21	22	18	11	14	21
EPT richness	10	10	11	9	8	9	13
Biotic index	4.43	5.04	5.33	5.22	2.53	3.11	3.95
% Dominant taxon	21	21	31	48	37	29	31
% Collectors	66	94	94	93	28	54	85
% EPT	60	65	56	71	89	82	70
Shannon H	3.71	3.07	2.93	2.67	2.39	2.98	3.12
% Scrapers plus shredders	16	4	3	6	33	33	11
# Predator taxa	4	5	5	3	3	1	3
% Multivoltine	17	42	50	38	8	17	37
Metric score							
Taxa richness	2	2	2	2	0	1	2
EPT richness	3	3	3	3	2	3	3
Biotic index	3	2	2	2	3	3	3
% Dominant taxon	3	3	2	1	2	3	2
% Collectors	2	1	1	1	3	3	1
% EPT	3	3	3	3	3	3	3
Shannon H	3	3	2	2	1	2	3
% Scrapers plus shredders	2	2	2	2	3	3	2
# Predator taxa	2	2	2	1	1	3	1
% Multivoltine	3	2	2	3	3	3	3
Total score (maximum = 30)	26	23	21	20	21	24	23
Percent of maximum	87	77	70	67	70	80	77
Use support*	**FULL**	**FULL**	**PART**	**PART**	**PART**	**FULL**	**FULL**

* See table 3 for use support designations

Table 5. Reference values and tentative criteria for assigning scores to metrics based on percent comparability to reference values (from Bollman 1997).

metric	*Musselshell River reference 1997*[1]	*Scoring criteria*[2] *3*	*2*	*1*	*0*	*
Taxa richness	24	>85%	85-75%	75-60%	<60%	a
EPT richness	10	>80%	80-50%	50-35%	<35%	a
Biotic index	4.43	>90%	90-80%	80-70%	<70%	b
% dominant taxon	21	>75%	75-60%	60-50%	<50%	b
% collector (G+FF)	66	>90%	90-75%	75-60%	<60%	b
% EPT	60	>85%	85-75%	75-40%	<40%	a
Shannon diversity	3.71	>90%	90-80%	80-70%	<70%	a
% scrapers + shredders	16	>70%	70-50%	50-25%	<25%	a
Predator taxa richness	4	>60%	60-50%	50-40%	<40%	a
% multivoltine	17	>35%	35-25%	25-15%	<15%	b

1. Musselshell River reference values are from the site at Daisy Dean Creek in 1997.
2. Scoring criteria are based on an analysis of metric ranges for 17 Plains ecoregions sites in four years of data collected by the Montana Department of Environmental Quality (Bollman, 1997, unpublished).

*a = score is ratio of study site value to reference value x 100
*b = score is ratio of reference value to study site value x 100

Table 6a. Percent of reference, metric scores, and bioassessments for six Musselshell River sites. Musselshell River reference. September 5, 1990.

Metric	*at Daisy Dean*	*at Harlowton*	*at Deadman's Basin*	*at Careless Ck.*	*at Parrot's*	*at Roundup*
Taxa richness	88	75	58	50	54	75
EPT richness	100	80	50	90	80	100
Biotic index	98	100	99	100	100	100
% Dominant taxon	100	66	100	54	88	60
% Collectors	84	87	100	70	74	73
% EPT	95	83	100	63	65	69
Shannon H	100	89	90	70	82	82
% Scrapers plus shredders	69	100	13	19	56	25
# Predator taxa	25	50	75	25	25	25
% Multivoltine	85	77	46	85	74	100
Metric score						
Taxa richness	3	2	0	0	0	2
EPT richness	3	2	2	3	2	3
Biotic index	3	3	3	3	3	3
% Dominant taxon	3	2	3	1	3	2
% Collectors	2	2	3	1	1	1
% EPT	3	2	3	1	1	1
Shannon H	3	2	2	1	2	2
% Scrapers plus shredders	2	3	0	0	2	1
# Predator taxa	0	1	3	0	0	0
% Multivoltine	3	3	3	3	3	3
Total score (maximum = 30)	25	22	22	13	17	18
Percent of maximum	83	73	73	43	57	60
Use support*	**FULL**	**PART**	**PART**	**PART**	**PART**	**PART**

* See table 3 for use support designations

Table 6b. Percent of reference, metric scores, and bioassessments for six Musselshell River sites. Musselshell River reference. September, 1997.

Metric	*at Daisy Dean*	*at Harlowton*	*at Deadman's Basin (Rep.1)*	*at Deadman's Basin (Rep.2)*	*at Careless Ck.*	*at Parrot's*	*at Roundup*
Taxa richness	100	88	92	75	46	58	88
EPT richness	100	100	100	90	80	90	100
Biotic index	100	88	83	85	100	100	100
% Dominant taxon	100	100	68	44	57	72	68
% Collectors	100	70	70	71	100	100	78
% EPT	100	100	93	100	100	100	100
Shannon H	100	89	90	72	64	80	84
% Scrapers plus shredders	100	100	13	38	100	100	69
# Predator taxa	100	100	100	75	75	25	75
% Multivoltine	100	40	34	45	100	100	46
Metric score							
Taxa richness	3	3	3	2	0	0	3
EPT richness	3	3	3	3	2	3	3
Biotic index	3	2	2	2	3	3	3
% Dominant taxon	3	3	2	0	1	2	2
% Collectors	3	1	1	1	3	3	2
% EPT	3	3	3	3	3	3	3
Shannon H	3	2	1	1	0	2	2
% Scrapers plus shredders	3	1	0	1	3	3	2
# Predator taxa	3	3	3	3	3	0	3
% Multivoltine	3	3	2	3	3	3	3
Total score (maximum = 30)	30	24	20	19	21	22	26
Percent of maximum	100	80	67	63	70	73	87
Use support	**FULL**	**FULL**	**PART**	**PART**	**PART**	**PART**	**FULL**

* See table 3 for use support designations

LITERATURE CITED

Barbour M.T. and J.B.Stribling. 1991. Use of habitat assessment in evaluating the biological integrity of stream communities. Pages 25-38 in *Biological Criteria: Research and Regulation, Proceedings of a Symposium, 12-13 December 1990.* U.S.EPA-440-5-91.

Bollman, W. 1997. 1996 Aquatic macroinvertebrate survey: Big Dry and Little Dry Creeks, Garfield County, Montana. Report prepared for the Montana Department of Environmental Quality. Helena, Montana.

Bollman, W. 1998. Improving Stream Bioassessment Methods for the Montana Valleys and Foothill Prairies Ecoregion. Unpublished Master's Thesis. University of Montana.

Bukantis, Bob. 1998. Rapid bioassessment macroinvertebrate protocols: sampling and sample analysis SOP's. Montana Department of Environmental Quality. Water Quality Division. Working draft.

Bukantis, Bob. 1991. Macroinvertebrate-based assessment of the Musselshell River. Report prepared for the Montana Department of Health and Environmental Sciences. Helena, Montana.

Fore, L. S., J.R. Karr and R.W. Wisseman. 1996. Assessing invertebrate responses to human activities: evaluating alternative approaches. Jounal of the North American Benthological Society 15(2):212-231.

Hynes, H.B.N. 1970. *The Ecology of Running Waters.* University of Toronto Press.

Karr, J.R. and D.R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 11:249-256.

Plafkin, J.L., M.T. Barbour, K.D. Porter and S.K. Gross. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers. Benthic Macroinvertebrates and Fish. U.S. EPA. 444/ 4-89-001.

APPENDIX

Macroinvertebrate Taxonomic Data

Upper Musselshell below Daisy Dean Creek 970924 R1

Taxon	#	%	BI[2]	FFG[1]
Oligochaeta:Naididae	3	1.01	10	CG
Physella	2	0.67	8	SC
Gyraulus	1	0.34	8	SC
Acari	3	1.01	5	PA
TOTAL: MISC. TAXA	9	3.02		
Acentrella turbida	2	0.67	4	CG
Baetis tricaudatus	30	10.07	4	CG
Stenonema	5	1.68	3.5	SC
Paraleptophlebia heteronea	5	1.68	1	CG
Tricorythodes minutus	62	20.81	4	CG
TOTAL: EPHEMEROPTERA	104	34.90		
Isoperla	10	3.36	2	PR
TOTAL: PLECOPTERA	10	3.36		
Helicopsyche borealis	14	4.70	3	SC
Hydropsyche	32	10.74	5	CF
Lepidostoma	3	1.01	1	SH
Oecetis	17	5.70	8	PR
TOTAL: TRICHOPTERA	66	22.15		
Optioservus	23	7.72	5	SC
Zaitzevia	2	0.67	4	CG
TOTAL: COLEOPTERA	25	8.39		
Atherix	2	0.67	5	PR
Simulium	40	13.42	5	CF
Hexatoma	22	7.38	2	PR
TOTAL: DIPTERA	64	21.48		
Cricotopus Trifascia Gr.	6	2.01	6	CG
Eukiefferiella Devonica Gr.	10	3.36	8	CG
Parametriocnemus	1	0.34	5	CG
Rheocricotopus	1	0.34	4	CG
Tvetenia Bavarica Gr.	2	0.67	5	CG
TOTAL: CHIRONOMIDAE	20	6.71		
GRAND TOTAL	298	100.00		

Aquatic Macroinvertebrate Data: Upper Musselshell below Daisy Dean Creek
970924R1

Percent of sample used	7
Subsample size	298
Percent EPT	60
Taxa richness	24
EPT richness	10
Biotic Index	4.43
Percent dominant taxon	20.81
Percent dominance of five dominant taxa	62.76
Percent dominance of ten dominant taxa	87.26
Percent collectors (gatherers plus filterers)	65.8
Percent scrapers plus shredders	16.1
Percent Hydropsychinae of Trichoptera	48
Metals tolerance index	4.22
Shannon H (log2)	3.71
Evenness	.81
Brillouin H	2.44
Simpson D	.10
EPT/Chironomidae	9.00
CTQa	78.92
Percent Baetidae of Ephemeroptera	31
%Ephemeroptera	34.91
%Plecoptera	3.36
%Trichoptera	22.15
%Coleoptera	8.39
%Diptera	21.47
%Chironomidae	6.72
Multivoltine	16.78
Univoltine	74.33
Semivoltine	8.89

Functional Feeding Groups	# taxa	% abundance
Predator	4	17.11
Collector-gatherer	11	41.63
Collector-filterer	2	24.16
Scraper	5	15.11
Shredder	1	1.01

Estimated total number of organisms	4470
Estimated number collected per foot	135
Estimated number collected per minute	4470

Macroinvertebrate Taxonomic Data

Musselshell River below Harlowton 970924 R2

Taxon	#	%	BI[2]	FFG[1]
Oligochaeta: Ophiodonais serpentina	8	2.55	10	CG
TOTAL: MISC. TAXA	8	2.55		
Baetis tricaudatus	62	19.75	4	CG
Stenonema	13	4.14	3.5	SC
Choroterpes	6	1.91	2	CG
Tricorythodes minutus	66	21.02	4	CG
TOTAL: EPHEMEROPTERA	147	46.82		
Claassenia sabulosa	1	0.32	3	PR
Skwala	1	0.32	3	PR
TOTAL: PLECOPTERA	2	0.64		
Brachycentrus occidentalis	1	0.32	2	CF
Cheumatopsyche	3	0.96	5	CF
Hydropsyche	49	15.61	5	CF
Oecetis	1	0.32	8	PR
TOTAL: TRICHOPTERA	54	17.20		
Optioservus	1	0.32	5	SC
TOTAL: COLEOPTERA	1	0.32		
Simulium	6	1.91	5	CF
Hexatoma	1	0.32	2	PR
TOTAL: DIPTERA	7	2.23		
Cricotopus	6	1.91	7	CG
Cricotopus Trifascia Gr.	63	20.06	6	CG
Eukiefferiella Devonica Gr.	22	7.01	8	CG
Eukiefferiella Pseudomontana Gr.	1	0.32	8	CG
Microtendipes	1	0.32	6	CG
Parametriocnemus	1	0.32	5	CG
Thienemannimyia	1	0.32	5	PR
TOTAL: CHIRONOMIDAE	95	30.25		
GRAND TOTAL	314	100.00		

Aquatic Macroinvertebrate Data: Musselshell River below Harlowton 970924 R2

Percent of sample used	7
Subsample size	314
Percent EPT	65
Taxa richness	21
EPT richness	10
Biotic Index	5.04
Percent dominant taxon	21.02
Percent dominance of five dominant taxa	83.45
Percent dominance of ten dominant taxa	95.87
Percent collectors (gatherers plus filterers)	94.0
Percent scrapers plus shredders	4.5
Percent Hydropsychinae of Trichoptera	96
Metals tolerance index	5.53
Shannon H (log2)	3.07
Evenness	.70
Brillouin H	2.03
Simpson D	.15
EPT/Chironomidae	2.14
CTQa	80.67
Percent Baetidae of Ephemeroptera	42
%Ephemeroptera	46.82
%Plecoptera	.64
%Trichoptera	17.21
%Coleoptera	.32
%Diptera	2.23
%Chironomidae	30.26
Multivoltine	41.64
Univoltine	56.13
Semivoltine	2.23

Functional Feeding Groups	# taxa	% abundance
Predator	5	1.60
Collector-gatherer	10	75.17
Collector-filterer	4	18.80
Scraper	2	4.46
Shredder	0	.00

Estimated total number of organisms	4710
Estimated number collected per foot	188
Estimated number collected per minute	4710

Macroinvertebrate Taxonomic Data

Musselshell River at Deadman's Basin diversion	1.1		1.2			
Taxon	#	%	#	%	BI[2]	FFG[1]
Oligochaeta: Tubificidae	2	0.66			10	CG
Oligochaeta: Naididae			1	0.31	10	CG
TOTAL: MISC. TAXA	2	0.66	1	0.31		
Acentrella turbida	44	14.62			4	CG
Baetis flavistriga			19	5.83	5	CG
Baetis tricaudatus	12	3.99	11	3.37	4	CG
Leucrocuta	4	1.33	12	3.68	4	SC
Stenonema	4	1.33	1	0.31	3.5	SC
Isonychia			1	0.31	2.5	CF
Tricorythodes minutus	2	0.66	11	3.37	4	CG
TOTAL: EPHEMEROPTERA	66	21.93	55	16.87		
Isogenoides	3	1.00	2	0.61	3	PR
Isoperla	1	0.33			2	PR
TOTAL: PLECOPTERA	4	1.33	2	0.61		
Brachycentrus occidentalis	1	0.33			2	CF
Cheumatopsyche	4	1.33	17	5.21	5	CF
Hydropsyche	92	30.56	158	48.47	5	CF
Oecetis	1	0.33			8	PR
TOTAL: TRICHOPTERA	98	32.56	175	53.68		
Optioservus	2	0.66	6	1.84	5	SC
TOTAL: COLEOPTERA	2	0.66	6	1.84		
Simulium	14	4.65	10	3.07	5	CF
Hexatoma	1	0.33	1	0.31	2	PR
TOTAL: DIPTERA	15	4.98	11	3.37		
Cardiocladius	1	0.33	1	0.31	5	PR
Cricotopus	1	0.33			7	CG
Cricotopus Trifascia Gr.	78	25.91	50	15.34	6	CG
Eukiefferiella Claripennis Gr.	2	0.66			8	CG
Eukiefferiella Devonica Gr.	26	8.64	20	6.13	8	CG
Orthocladius	2	0.66	4	1.23	6	CG
Polypedilum	4	1.33			6	CG
Rheocricotopus			1	0.31	4	CG
TOTAL: CHIRONOMIDAE	114	37.87	76	23.31		
GRAND TOTAL	301	100.00	326	100.00		

Aquatic Macroinvertebrate Data: Musselshell River below Deadman's Basin diversion.

Sample:	3.1	3.2
% of sample used:	7	15
Subsample size	301	326
Taxa richness	22	18
EPT richness	11	9
Biotic index	5.33	5.22
% Dominant taxon	30.56	48.47
% EPT	56	71
% Collectors (g+f)	94.3	92.95
% Scrapers + Shredders	3.3	5.83
% Hydropsychinae of Trich	98	100
Metals tolerance index	5.86	5.75
Shannon Diversity (log2)	2.93	2.67
EPT/Chironomidae	1.47	3.05
CTQa	81.91	85.11
%Baetidae of Ephemeroptera	85	54
% Coleoptera	.66	1.84
% Diptera	4.98	3.38
% Chironomidae	37.86	23.32
% Ephemeroptera	21.93	16.87
% Plecoptera	1.33	.61
% Trichoptera	32.55	53.68
% multivoltine	50.33	37.81
% univoltine	48.34	60.20
% semivoltine	1.33	1.99

Functional Feeding Grp.	%RA	# taxa	%RA	# taxa
Filterers	36.87	4	56.07	4
Collector-Gatherers	57.46	10	35.89	8
Shredders	0	0	0	0
Scrapers	3.32	3	5.83	3
Predators	2.32	5	1.23	3

Est. total number of organisms	4515	2173
Est. number collected per foot	174	72
Est. number collected per minute	4515	2173

Macroinvertebrate Taxonomic Data

Musselshell River below Careless Creek 970924 R4

Taxon	#	%	BI[2]	FFG[1]
Acentrella turbida	5	5.00	4	CG
Baetis tricaudatus	1	1.00	4	CG
Rhithrogena	32	32.00	0	SC
Stenonema	1	1.00	3.5	SC
Isonychia	1	1.00	2.5	CF
TOTAL: EPHEMEROPTERA	40	40.00		
Isogenoides	37	37.00	3	PR
TOTAL: PLECOPTERA	37	37.00		
Cheumatopsyche	4	4.00	5	CF
Hydropsyche	8	8.00	5	CF
TOTAL: TRICHOPTERA	12	12.00		
Simulium	9	9.00	5	CF
Hexatoma	1	1.00	2	PR
TOTAL: DIPTERA	10	10.00		
Thienemannimyia	1	1.00	5	PR
TOTAL: CHIRONOMIDAE	1	1.00		
GRAND TOTAL	100	100.00		

Aquatic Macroinvertebrate Data: Musselshell River below Careless Creek 970924 R4

Percent of sample used	100
Subsample size	100
Percent EPT	89
Taxa richness	11
EPT richness	8
Biotic Index	2.53
Percent dominant taxon	37.00
Percent dominance of five dominant taxa	91.00
Percent dominance of ten dominant taxa	99.00
Percent collectors (gatherers plus filterers)	28.0
Percent scrapers plus shredders	33.0
Percent Hydropsychinae of Trichoptera	.00
Metals tolerance index	2.72
Shannon H (log2)	2.39
Evenness	.69
Brillouin H	1.51
Simpson D	.25
EPT/Chironomidae	89.00
CTQa	68.45
Percent Baetidae of Ephemeroptera	15
%Ephemeroptera	40.00
%Plecoptera	37.00
%Trichoptera	12.00
%Coleoptera	.00
%Diptera	10.00
%Chironomidae	1.00
Multivoltine	8.25
Univoltine	91.75
Semivoltine	.00

Functional Feeding Groups	# taxa	% abundance
Predator	3	39.00
Collector-gatherer	2	6.00
Collector-filterer	4	22.00
Scraper	2	33.00
Shredder	0	.00

Estimated total number of organisms	100
Estimated number collected per foot	3
Estimated number collected per minute	100

Macroinvertebrate Taxonomic Data

Musselshell River at Parrott's 970924 R5

Taxon	#	%	BI[2]	FFG[1]
Acentrella turbida	19	10.50	4	CG
Baetis tricaudatus	6	3.31	4	CG
Rhithrogena	52	28.73	0	SC
Stenonema	8	4.42	3.5	SC
Parameletus	2	1.10	1	CG
Tricorythodes minutus	2	1.10	4	CG
TOTAL: EPHEMEROPTERA	89	49.17		
Isogenoides	23	12.71	3	PR
TOTAL: PLECOPTERA	23	12.71		
Cheumatopsyche	22	12.15	5	CF
Hydropsyche	14	7.73	5	CF
TOTAL: TRICHOPTERA	36	19.89		
Simulium	29	16.02	5	CF
TOTAL: DIPTERA	29	16.02		
Cricotopus	1	0.55	7	CG
Cryptochironomus	1	0.55	8	CG
Eukiefferiella Brehmi Gp.	1	0.55	8	CG
Eukiefferiella Devonica Gr.	1	0.55	8	CG
TOTAL: CHIRONOMIDAE	4	2.21		
GRAND TOTAL	181	100.00		

Aquatic Macroinvertebrate Data: Musselshell River at Parrott's 970924 R5

Percent of sample used	100
Subsample size	181
Percent EPT	82
Taxa richness	14
EPT richness	9
Biotic Index	3.11
Percent dominant taxon	28.73
Percent dominance of five dominant taxa	80.11
Percent dominance of ten dominant taxa	97.77
Percent collectors (gatherers plus filterers)	54.1
Percent scrapers plus shredders	33.2
Percent Hydropsychinae of Trichoptera	.00
Metals tolerance index	3.40
Shannon H (log2)	2.98
Evenness	.78
Brillouin H	1.95
Simpson D	.15
EPT/Chironomidae	37.00
CTQa	83.79
Percent Baetidae of Ephemeroptera	28
%Ephemeroptera	49.16
%Plecoptera	12.71
%Trichoptera	19.88
%Coleoptera	.00
%Diptera	16.02
%Chironomidae	2.20
Multivoltine	16.99
Univoltine	83.01
Semivoltine	.00

Functional Feeding Groups	# taxa	% abundance
Predator	1	12.71
Collector-gatherer	8	18.21
Collector-filterer	3	35.90
Scraper	2	33.15
Shredder	0	.00

Estimated total number of organisms	181
Estimated number collected per foot	5
Estimated number collected per minute	181

Macroinvertebrate Taxonomic Data

Musselshell River below Roundup 970925 R4

Taxon	#	%	BI[2]	FFG[1]
Cladocera	2	0.61	8	CF
TOTAL: MISC. TAXA	2	0.61		
Ophiogomphus	1	0.30	5	PR
TOTAL: ODONATA	1	0.30		
Acentrella turbida	103	31.21	4	CG
Baetis flavistriga	8	2.42	5	CG
Baetis tricaudatus	11	3.33	4	CG
Rhithrogena	31	9.39	0	SC
Stenonema	4	1.21	3.5	SC
Traverella	13	3.94	2	CG
Choroterpes	1	0.30	2	CG
Isonychia	4	1.21	2.5	CF
Tricorythodes minutus	1	0.30	4	CG
TOTAL: EPHEMEROPTERA	176	53.33		
Isogenoides	11	3.33	3	PR
TOTAL: PLECOPTERA	11	3.33		
Hydropsychidae	20	6.06	4	CF
Cheumatopsyche	21	6.36	5	CF
Neotrichia	2	0.61	2	SC
TOTAL: TRICHOPTERA	43	13.03		
Ordobrevia nubifera	1	0.30	5	CG
TOTAL: COLEOPTERA	1	0.30		
Simulium	75	22.73	5	CF
TOTAL: DIPTERA	75	22.73		
Cricotopus Trifascia Gr.	18	5.45	6	CG
Eukiefferiella Claripennis Gr.	1	0.30	8	CG
Eukiefferiella Devonica Gr.	1	0.30	8	CG
Thienemannimyia	1	0.30	5	PR
TOTAL: CHIRONOMIDAE	21	6.36		
GRAND TOTAL	330	100.00		

Aquatic Macroinvertebrate Data: Musselshell River below Roundup	970925 R4
Percent of sample used	50
Subsample size	330
Percent EPT	70
Taxa richness	21
EPT richness	13
Biotic Index	3.95
Percent dominant taxon	31.21
Percent dominance of five dominant taxa	75.75
Percent dominance of ten dominant taxa	94.22
Percent collectors (gatherers plus filterers)	84.8
Percent scrapers plus shredders	11.2
Percent Hydropsychinae of Trichoptera	95
Metals tolerance index	3.93
Shannon H (log2)	3.12
Evenness	.71
Brillouin H	2.06
Simpson D	.17
EPT/Chironomidae	10.95
CTQa	81.95
Percent Baetidae of Ephemeroptera	69
%Ephemeroptera	53.31
%Plecoptera	3.33
%Trichoptera	13.03
%Coleoptera	.30
%Diptera	22.73
%Chironomidae	6.35
Multivoltine	36.67
Univoltine	62.73
Semivoltine	.61

Functional Feeding Groups	# taxa	% abundance
Predator	3	3.93
Collector-gatherer	10	47.85
Collector-filterer	5	36.97
Scraper	3	11.21
Shredder	0	.00

Estimated total number of organisms	660
Estimated number collected per foot	18
Estimated number collected per minute	660